CLAIMS

What is claimed is:

1. A method of characterizing an intermediate frequency (IF) response of a receiver comprising:

determining an estimate of an actual IF response of the receiver from IF responses of the receiver under test measured for overlapping frequency bands and a set of conversion coefficients computed from the IF responses, such that the estimate reduces an effect of an uncertainty in knowledge of a radio frequency (RF) stimulus signal used in the IF response measurements.

2. The method of Claim 1 further comprising:

measuring the IF responses of a receiver for a plurality of the overlapping frequency bands;

computing the set of conversion coefficients from the measured IF responses.

3. The method of Claim 2, wherein measuring comprises averaging measurements of the IF frequency response at the overlapping frequency bands of the plurality.

4. The method of Claim 1, wherein the uncertainty in knowledge being a result of one or both of an uncertainty in knowledge of a baseband transmitter filter frequency response and an uncertainty in knowledge of a spectrum of a baseband stimulus signal.

5. The method of Claim 1, further comprising:

removing an effect of a radio frequency (RF) tilt in a magnitude response of an RF portion of the receiver.

6. The method of Claim 5, wherein removing the effect of the RF tilt comprises:

determining the estimate at a first setting of a local oscillator of the receiver to obtain a non-image estimate $\hat{X}(k)$;

adjusting the local oscillator to a second setting corresponding to an image IF response of the receiver relative to the first setting;

determining the estimate of the actual IF frequency response at the second setting to obtain an image estimate $\hat{X}_{image}(k)$; and

combining the non-image estimate $\hat{X}(k)$ and the image estimate $\hat{X}_{image}(k)$ response to cancel the effect of the RF tilt in the combined estimate of the IF response.

7. The method of Claim 6, wherein combining comprises computing a square-root of a product of the non-image estimate $\hat{X}(k)$ and the image estimated $\hat{X}_{image}(k)$.

8. The method of Claim 1, wherein the IF responses are measured for overlapping frequency bands comprising:

applying a radio frequency (RF) stimulus signal to an input of the receiver; and

measuring an IF output signal response at an output of the receiver for each of a plurality of the overlapping frequency bands.

9. The method of Claim 8, wherein measuring an IF output signal response further comprises computing a transfer characteristic for the IF output signal response measurement.

10. The method of Claim 8, wherein the RF stimulus signal is a broadband signal comprising one or both of a summation of a plurality of sinewaves and a periodic chirped waveform.

11. The method of Claim 10, wherein the broadband signal is a periodic broadband signal having a period that is a reciprocal of a measurement frequency resolution Δf, a step size or tuning resolution of the receiver being an integer multiple of the frequency resolution Δf, the step size or tuning resolution of the receiver being either a difference between center frequencies of adjacent frequency bands of the

plurality or a tuning resolution of a local oscillator of a downconversion stage of the receiver.

12. The method of Claim 1, wherein a conversion coefficient of the set defines a relationship between the actual IF frequency response and the IF frequency responses measured for overlapping frequency bands.

13. The method of Claim 12, wherein the relationship between the measured IF frequency responses and the actual IF frequency response is given by

$$Y_i(k) = a_i \cdot X(k) + N_i(k) \quad (7)$$

where a_i is an ith conversion coefficient of the set, $Y_i(k)$ is an ith measured IF frequency response, $X(k)$ is the actual IF frequency response, $N_i(k)$ is an introduced error, i is an index variable corresponding to an ith band of a IF response measurement, and k is an index, wherein individual values of the index k represent discrete frequencies point in the measurements.

14. The method of Claim 12, wherein the set of conversion coefficients are chosen to minimize a sum-square difference between the measured IF responses for a plurality of the overlapping frequency bands.

15. The method of Claim 12, wherein the set of conversion coefficients are computed comprising:

defining a set of half-band IF response measurements in terms of the IF response measurements for overlapped frequency band portions, such that a half of the half-band measurements correspond to IF frequency response measurements in upper half-bands of the overlapped frequency band portions, while another half of the half-band measurements correspond to IF frequency response measurements $Y(k)$ in lower half-bands of the overlapped frequency band portions.

16. The method of Claim 15, wherein defining a set of half-band measurements in terms of the measured IF responses comprises using an equation

$$Z_1(k) = Y_1(k) \quad k = 0, 1, \cdots, (N-1)$$
$$Z_2(k) = Y_2(k) \quad k = 0, 1, \cdots, (N-1)$$

and for $i = 2, 3, \cdots$ (8)

$$Z_{2i-1}(k) = Y_i(k) \qquad k = (i-1)N, (i-1)N+1, \cdots, iN-1$$
$$Z_{2i}(k) = Y_{i+1}(k) \qquad k = (i-1)N, (i-1)N+1, \cdots, iN-1$$

where $Z_i(k)$ is the set of half-band IF response measurements, $Y_i(k)$ is the measured IF responses, i is an index variable corresponding to an ith band of a measured IF response, k is an index for discrete frequency response measurement points within the ith band, and $2N+1$ is an integer representing the discrete frequency response measurement points measured in each ith band.

17. The method of Claim 16, wherein the conversion coefficients are defined in terms of another coefficient using an equation

$$a_{i+1} = b_i \cdot a_i; \quad i = 1, 2, \cdots \quad \text{and } a_1 = 1 \tag{9}$$

where a_i is a conversion coefficient, and b_i is the other coefficient.

18. The method of Claim 17, wherein an estimate of the other coefficient b_i is given in terms of the half-band IF response measurements $Z_i(k)$ as

$$b_i = \frac{\sum_{k=0}^{N-1} Z_{2i}[k + N(i-1)] \cdot Z^*_{2i-1}[k + N(i-1)]}{\sum_{k=0}^{N-1} |Z_{2i-1}[k + N(i-1)]|^2} \qquad i = 1, 2, 3, \cdots \tag{10a}$$

where Z^*_{2i-1} is the complex conjugate of Z_{2i-1}.

19. The method of Claim 17, wherein the other coefficient b_i is determined by averaging the set of half-band IF response measurements $Z_i(k)$ in the overlapping half bands.

20. The method of Claim 19, wherein averaging the set of half-band IF response measurements $Z_i(k)$ comprises using an equation

$$\hat{b}_i = \frac{1}{N}\sum_{k=0}^{N-1} \frac{Z_{2i}[k+N(i-1)]}{Z_{2i-1}[k+N(i-1)]} \qquad i = 1, 2, 3, \cdots \qquad (10b).$$

21. The method of Claim 1, wherein determining an estimate of an actual IF frequency response uses the set of conversion coefficients as weights to determine a weighted average of the IF response measurements for the overlapping frequency bands.

22. The method of Claim 21, wherein determining the estimate of an actual IF frequency response comprises converting the measured IF responses to half-band measurements, and using a relationship given by an equation

$$\hat{X}[k+(i-1)N] = \frac{1}{2}\left\{\frac{1}{a_{2i}} Z_{2i}[k+(i-1)N] + \frac{1}{a_{2i-1}} Z_{2i-1}[k+(i-1)N]\right\};$$
$$\text{for} \begin{cases} k = 0, 1, 2, \cdots, N-1 \\ i = 1, 2, 3, \cdots \end{cases} \qquad (11)$$

and where a_i are the conversion coefficients, $\hat{X}(k)$ is the actual frequency response estimate, $Z_i(k)$ are half-band IF response measurements, i is an index variable corresponding to an ith band of a measured IF response, k is an index for discrete frequency response measurement points within the ith band, and N is an integer representing the number of discrete frequency response measurement points measured in each ith band.

23. The method of Claim 1, further comprising reducing an effect of a delay misalignment, the delay misalignment being a random-added delay in the IF responses measured at the overlapping frequency bands.

24. The method of Claim 1, further comprising removing a delay misalignment from either the IF responses measured for the overlapping frequency bands or half-band IF response measurements corresponding to the measured IF responses before the set of conversion coefficients are computed from the IF responses.

25. The method of Claim 24, wherein removing a delay misalignment comprises finding a phase progression in a ratio of the measured IF responses from overlapping bands; multiplying the ratio by a complex conjugate of the phase progression to remove the phase progression; and optionally employing the ratio when the set of conversion coefficients is computed.

26. A method of characterizing an intermediate frequency (IF) response of a receiver to reduce an effect of stimulus signal uncertainty, the method comprising:

measuring an IF response of a receiver at a plurality of overlapping frequency bands;

computing a set of conversion coefficients from the IF response measurements; and

determining an estimate of an actual IF frequency response using the IF response measurements and the conversion coefficients, the estimate reducing the effect of stimulus signal uncertainty used in measuring.

27. The method of Claim 26, wherein measuring comprises averaging measurements of the IF frequency response at the overlapping frequency bands of the plurality.

28. The method of Claim 26, further comprising:

removing an effect of a radio frequency (RF) tilt in a magnitude response of an RF portion of the receiver.

29. The method of Claim 26, wherein the set of conversion coefficients are chosen to minimize a sum-square difference between the measured IF responses for the plurality of overlapping frequency bands.

30. An intermediate frequency (IF) measurement system that characterizes an IF response of a receiver under test, the system comprising:

a signal generator that applies a radio frequency (RF) stimulus signal to the receiver under test;

an IF processor that receives and digitizes an IF response from the receiver under test, the IF response being responsive to the applied RF stimulus signal;

a controller that controls the signal generator, the receiver under test, and the IF processor, the controller processing the digitized IF response; and

a computer program stored in memory and executed by the controller, the computer program comprising instructions that, when executed, implement determining an estimate of an actual IF response of the receiver under test from IF responses of the receiver under test measured at overlapping frequency bands and a set of conversion coefficients computed from the measured IF responses, such that the estimate reduces an effect of uncertainties in knowledge of the RF stimulus signal.

31. The IF measurement system of Claim 30, wherein the instructions that implement determining an estimate comprises instructions that implement measuring the IF response of the receiver under test for each of the overlapping frequency bands; and computing the set of conversion coefficients from the measured IF responses.

32. The IF measurement system of Claim 30, wherein the computer program further comprises instructions that, when executed, implement removing an RF tilt in a magnitude response of an RF portion of the receiver under test.

33. An intermediate frequency (IF) measurement system that characterizes an IF response of a receiver under test, the system comprising:

a signal generator having an output, the signal generator producing a radio frequency (RF) stimulus signal at the signal generator output;

an IF processor having an output, the IF processor producing a digitized IF response at the processor output;

a controller having an input connected the processor output, a first output connected to an input of the signal generator, and a second output connected to a first input of the IF processor, the receiver under test being connected between a third output of the controller, the signal generator output, and a second input of the IF processor during characterization; and

a computer program executed by the controller, the computer program comprising instructions that, when executed, determine an estimate of an actual IF response of the receiver under test from IF responses of the receiver under test measured at overlapping frequency bands and a set of conversion coefficients computed from the measured IF responses.

34. The IF measurement system of Claim 33, wherein the signal generator comprises:

a baseband stimulus source;

a transmitter baseband filter connected to an output of the baseband stimulus source;

an upconverter connected to an output of the transmitter baseband filter, the upconverter comprising a tunable local oscillator; and

a transmitter RF filter connected between the upconverter and the signal generator output.

35. The IF measurement system of Claim 33, wherein the signal generator comprises:

an RF stimulus source; and

a transmitter RF filter connected between an output of the RF stimulus source and the signal generator output.

36. The IF measurement system of Claim 33, wherein the IF processor comprises an analog-to-digital converter that converts an IF output signal from an output of the receiver under test into a digitized IF response.

37. The IF measurement system of Claim 33, wherein the controller is one or more of a general-purpose computer and a specialized processing engine or element.

38. The IF measurement system of Claim 37, wherein the specialized processing engine or element comprises one or both of an embedded microprocessor and an embedded microcomputer.

39. The IF measurement system of Claim 33, wherein the computer program is stored in one or both of memory of the controller and a computer readable media readable by the controller.

40. The IF measurement system of Claim 33, wherein the computer program further comprises instructions that implement measuring the IF response of the receiver under test for the overlapping frequency bands; and instructions that implement computing the set of conversion coefficients from the measured IF responses, and wherein the computer program optionally further comprises instructions that implement one or both of removing an RF tilt in a magnitude response of an RF portion of the receiver under test and removing a delay misalignment from either the measured IF responses or half-band IF measurements corresponding to the measured IF responses prior to computing the set of conversion coefficients.